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Art. XIV.—*Some Sap-staining Organisms of Pinus Radiata, D. Don, in Victoria, Australia.*

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A considerable amount of attention has been paid to fungi responsible for sap-stain in the Northern Hemisphere, but as far as I know there have only been two reports concerning sap-stain from Australia and New Zealand. The first(13) deals with the staining of *Pinus radiata* (syn. *P. insignis*) boards by *Ceratostomella* sp. in New Zealand, and the second(8) with staining which was cited as being due to the same genus, in pine timber in Queensland.

I. Origin of Forms Dealt with.

The sap-staining or blue-staining organisms dealt with in this report were isolated from *P. radiata* timber in all three cases.

(*a*) *Hormonema dematioides* Lagerberg and Melin(6). This organism was isolated from timber kindly sent by the Forests Commission of Victoria. *P. radiata* boards from Castlemaine were marred by light neutral-gray to green-black streaks(9). The transverse surface showed the characteristic staining in radial sectors. When samples of the three lots of material were split, the staining was found to penetrate throughout the boards.

(*b*) *Ceratostomella* sp., Form A and Form B. I am indebted to Mr. J. E. Cummins, of the Council for Scientific and Industrial Research, for cultures of these forms and for specimens of timber stained by them.

Form A was isolated from case stock from Somerville, Victoria. Attention was first directed towards staining caused by this form when some very badly stained fruit-cases which had been made up in the green condition were examined. The previous history is unknown.

Form B was isolated from case stock from Redhill, Victoria. *Pinus radiata* sapwood, after being felled and cut into case ends and sides at Redhill, Victoria, was immediately sent to the case manufacturers, where it was stacked out to dry. After about three weeks, while the material was still in the stacks, blue streaks appeared on the surfaces of the sapwood pieces. This condition rapidly grew worse until entire surfaces were badly blued and perithecia appeared in profusion. The staining degraded the stock, rendering it unfit for use in best class cases.

II. Methods of Isolation of Organisms.

In order to isolate the organisms responsible for the blueing, two methods were employed:—

(*a*) In the case of *Ceratostomella* sp., Forms A and B, where perithecia were present, one of these was removed with sterile needles and plated on to malt agar.

(*b*) In the case of *Hormonema dematioides*, where no perithecia were present, and as an alternative method for the isolation of Forms A and B, the following method was employed:—The surface of a sample of the infected wood was cleaned with mercuric chloride solution 1 : 1000 to eliminate chances of contamination with surface organisms. A tomahawk was sterilized similarly. After chopping through the board to expose a tangential surface, a small sliver of the blued interior was dug out by means of flame-sterilized chisel-forceps and emplanted in a malt agar slope.

Pure cultures were obtained by transferring to plain agar and back again to malt agar. Cultures were also grown on starch media and pine- and corn-meal media.

III. Methods of Re-infection.

In order to test the pathogenicity of the forms isolated, pure cultures were used to infect clean *P. radiata* blocks.

P. radiata sapwood was cut up into blocks 4″ x 1″ x 1″ (approximately). These were put into flasks on a small pad of cotton wool and were sterilized for half an hour at half an atmosphere pressure. When cold, a quantity of sterile water or prune juice was added and the blocks were infected by inoculating transverse, radial, and tangential surfaces with a portion cut from a young culture of the organism growing on malt agar. The cultures were cut so that each piece of inoculum consisted of a young growing edge of culture together with the adjacent portion of older growth. The flasks were plugged with cotton wool and a cellophane cap was tied over the plug. Flasks were incubated at room temperature during the warm months and at a constant temperature of 26° C. during the winter. After three weeks the organism was re-isolated from the blued blocks in the manner described previously.

In the first inoculation experiment the blocks were too wet to permit of any staining by the fungus. At the end of the experiment the moisture content (based on the oven-dry weight) of two of the blocks was determined and found to be 191 and 158 per cent. respectively.

In subsequent inoculation experiments with the moisture content in the neighbourhood of 100 per cent., the organisms were found to stain the blocks throughout.

For the purpose of examining the distribution and nature of the organism within infected wood, small blocks, 1 cm. square approximately, were cut from the experimental blocks and boiled in water until they were fully saturated. Then radial and tangential sections were cut from them and stained by Cartwright's method and mounted in balsam(1).

IV. Description of Organisms.

(A) Hormonema dematioides Lagerberg and Melin.

This fungus, which shows a great variety of form in the habit of its mycelium, was first described by Lagerberg, Lündberg, and Melin in "Blueing in Pine and Spruce"(6), as occurring in sawn-pine and spruce and living pine-needles.

1. *Cultural characters.*

The culture on malt agar commences growth as a colourless mat which in a few days takes on a greenish tinge. This darkens rapidly and in older cultures the upper and lower surfaces both show as a deep green-black. Growth occurs either regularly, in a concentric fashion, or more irregularly, in the form of fan-shaped outgrowths and small bays which indent the periphery of the culture. The surface is slightly roughened or more coarsely corrugated. In cultures from freshly isolated strains practically the whole surface becomes covered by dirty whitish moist masses of conidia. When the strain becomes older, conidial production is not so abundant, and the surface of cultures become covered with a brown air mycelium.

2. *Mycelium.*

Young hyphae are hyaline, non-septated, and sparingly branched. Further back in the slightly older parts of the plate, septa occur at frequent intervals. This fungus is interesting in that the mycelium shows such a number of types of modification. The following types were noted:—

(*a*) Ordinary longicellular hyphae with straight-sided cells and lenticular septa (Fig. 1).

(*b*) Brevicellular hyphae with rounded sides and lenticular septa (Fig. 2).

(*c*) As the mycelium ages the walls become enormously thickened, sometimes with granular excrescences, and are greenish-brown. The lenticular transverse septa show up well and very often longitudinal and oblique septa occur also (Fig. 4). If only transverse septa are present, the hyphae appear as moniliform chains (Fig. 3). In examining the central part of a month-old culture, it is found that these moniliform chains tend to break up into bicellular portions with thick walls (Fig. 5).

(*d*) The peculiar resorption phenomena noted by Lagerberg and Melin were also noticed, but no cases of such an extreme type as they depicted were observed. This phenomenon consists of a thinning of the lateral thick walls of a portion of a hypha and the loss of the cell contents in this region. In parts where resorption phenomena occurred, it was found occasionally that the part of the hypha which retained its cell contents sprouted, and from one of its ends a branchlet grew which penetrated the outer wall of the old hypha (Fig. 6).

(*e*) *Coniothecium*-like groups of cells often occur along the length of a hypha which is just commencing to thicken its walls. These are little groups of very thick-walled cells which extend out further than the diameter of the hypha in which they are situated (Fig. 7).

(*f*) On the surface of the culture little dark crusts develop concentrically. These appear to mark the situation of most abundant spore production, since on examination they are seen to consist of moniliform chains of thick-walled cells which are covered with spores, and inside this zone of crusts the moist white spore masses occur.

3. *Spore Production.*

Spores are produced anywhere on the surface of the older thick-walled hyphae, thus forming a kind of palisade layer (Fig. 8). Each spore is large, rounded at both ends, being either oval or with a slight pyriform tendency, and contains from one to four oil globules at each pole (Fig. 9).

Size.—Length, range from 5.1 to 17.0μ; average, 9.0μ.
Breadth, ,, ,, 2.5 to 5.9μ average, 3.8μ.

Spores are occasionally septated.

4. *Air Mycelium.*

This occurs, as already stated, only on cultures from older strains. It is generally brown, floccose, and not very abundant. The hyphae composing it are thickish-walled and longicellular and become wefted together in ropey strands.

Very often hyphae become enormously thickened—single cells proliferating to give large clumps.

Lagerberg, &c., only note that these occur in wood, but probably their *Coniothecium* forms are the forerunners of such clumps.

5. *Distribution of the Fungus in Wood.*

In a transverse cut across a piece of infected timber, it is seen that the surface is stained, not uniformly, but in dark radial wedges tapering from the periphery to the heart. The border line between sap and heartwood was noticed because of the abrupt cessation of the stain at the inner limit of the sapwood (Fig. 11).

On the tangential and radial surfaces of infected wood are often found the dark crusts which are present in cultures. In sections of the stained wood it is found that hyphae are most abundant in the rays, which appear as dark lines to the naked eye.

The rays are found to be completely disorganized in many cases. Sometimes only the ray tracheids remain intact. The hyphae here are mostly of the longicellular thick-walled type, but may become brevicellular, and occasionally *Coniothecium* groups occur along their length. Resin canals are usually nearly as full of hyphae as are the rays, and tracheids are also entered. Here they run a sinuous course and are sparingly branched. The hyphae appear to use the pits as the sole means of crossing from one element to another (Fig. 12). Sometimes enormously proliferated hyphae like those present in the air mycelium are seen in the resin canals and tracheids.

Lagerberg, &c., noted that spores were always very abundant in their sections. I have scarcely ever found any spores.

(B) Ceratostomella spp.

1. *Historical Outline of* Ceratostomellas *causing sap-stain in Timber.*

In 1822, Fries(2) described *Ceratostoma piliferum*, which by later mycologists was not treated as a uniform species. In 1869-70, Fuchel(3) described four forms of this species affecting various trees, but it was not until 1878 that Hartig first connected sap-stain with fungi, and described a species causing blueing, which he thought might belong to *Cerastostoma piliferum* Fr. This species was therefore regarded as the specific blueing fungus until 1906. In 1878, Saccardo(10) separated *Ceratostomella* from *Cerastostoma* because of its colourless spores, and in 1887 the old *C. piliferum* was put into this new genus by Winter(12). This species still included several forms within itself as it did originally.

In 1903, von Schrenck(11) described blueing of timber in North America as due to *Ceratostomella pilifera* (Fr.) Wint. Münch(7) in 1907 sorted out the confusion of blueing of timber in Germany and found the name, *C. pilifera* (Fr.) Wint., covered four separate species of *Ceratostomella* and one new genus as follows:—

(i) *C. Pini.*
(ii) *C. coerulea.*
(iii) *C. Piceae.*
(iv) *C. cana.*
(v) *Endoconidiophora coerulescens.*

C. Pini was distinguished by the smallness of its perithecia, and the other three species of *Ceratostomella* can be separated by means of their conidial stage and other differences.

Endoconidiophora, with its *Ceratostomella*-like perithecia, is characterized by its peculiar conidial stage.

At about the same time (1906) Hedgcock(5) had been investigating the blueing fungi of North America. He retained the name *C. pilifera* (Fr.) Wint. for a very widely disseminated species, and also described numerous other species of *Ceratostomella* which were less important from the blueing point of view. Comparisons of the species of *Ceratostomella* of the two continents have not yet been undertaken systematically, and it is not known whether any of the European forms are identical with any of the American ones; or, if they are separate, which European species occur in America and vice versa. Lagerberg, &c.(6) note that in their experience with Swedish forms they have found that they may vary considerably, and they suggest that the species *C. capillifera, pilifera,* and *Schrenkiana* are connected with *C. coerulea.*

2. *Significance of* C. pilifera *(Fr.) Winter.*

In the attempt to establish the identity of *Ceratostomella* sp. Forms A and B, they were compared with *C. coerulea* Münch and *C. pilifera* (Fr.) Winter, cultures of which were obtained from Baarn, Holland, the former originally deposited there by Zachs and Melin, and the latter by Rumbold. There is some ambiguity in connexion with the latter species. As it stands—*C. pilifera* (Fr.) Winter—it should represent the old composite species before it was split up by Münch, but I have regarded it as a single species, and cultural observations show that it is so. In this case it must be the *C. pilifera* (Fries) Winter, described by Hedgcock in 1906 in his "Chromogenic Fungi which Discolour Wood"(5), although measurements of the form in culture do not correspond very closely with those given by Hedgcock for the same thing.

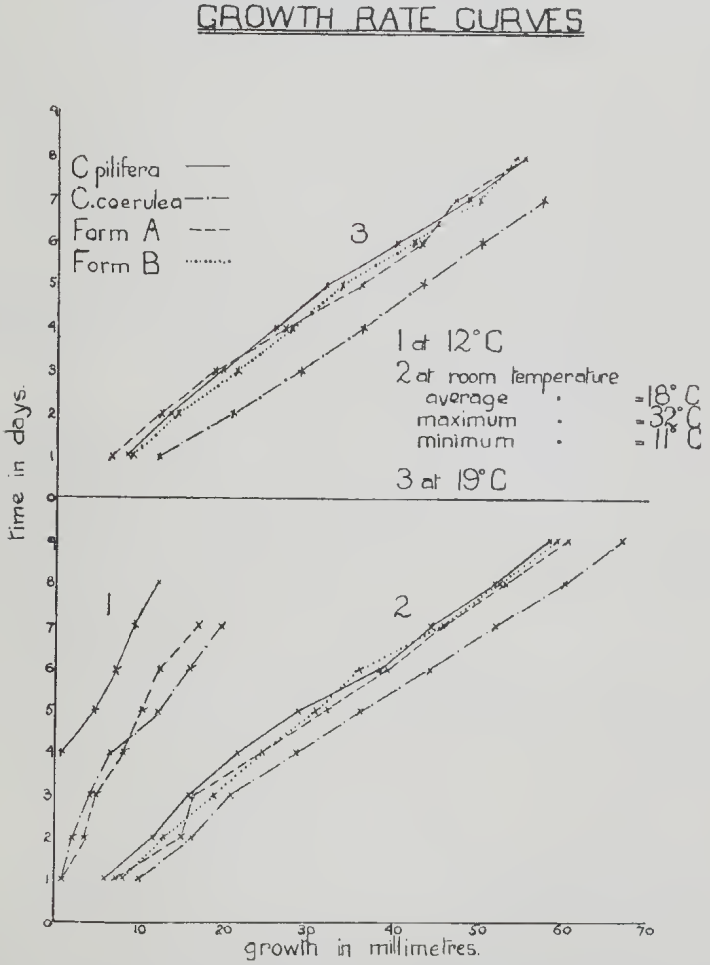
Lagerberg, &c., have noticed that a great deal of variation occurs in Swedish forms of *Ceratostomella.* This factor of variation may be the cause of disparity in this instance, since there seems to be no essential differences between the form described, and the form in culture.

3. *Results of Comparisons between* C. pilifera *(Fr.) Winter,* C. coerulea *Münch, and Recently Isolated Forms.*

Results of comparisons between *C. pilifera* (Fr.) Winter, and *C. coerulea* Münch, and the forms recently isolated—Form A from Somerville case stock, and Form B from Redhill case stock —seem to support the view of Lagerberg, &c., expressed at the end of their historical outline on page 7, that *C. pilifera* and other American forms may be connected to *C. coerulea*, since in some characters Forms A and B appear to approximate to *C. coerulea,* and in others to *C. pilifera.*

In general appearance, all four appear very similar, the main difference being that in *C. coerulea,* in contrast to the other three types, the thick-stranded erect hyphae are generally much better defined.

The two types of conidial fructification, viz.:—(*a*) the so-called "ear" arrangement of Lagerberg, &c., in which the projections on the fructiferous hyphae from which the conidia have fallen



are likened to ears; and (*b*) *Cephalosporium*-type (Figs. 13 and 14) in which conidia are arranged in grape-bunch clusters—occur in all four types, although it is found that the ear form which is most characteristic of *C. coerulea* is also predominant in Form B, whereas in Form A it is the *Cephalosporium*-type of fructification that one notices more especially.

The size of conidia in these four types is very variable—*C. pilifera,* and Forms A and B (Figs. 15 and 16), showing a very great range in length. *C. coerulea* is more conservative in this respect.

In shape, the perithecia of all four types appear similar—the venter is practically spherical, but is nearly always flattened basally. The neck is long and smooth and crowned by cilia. Perithecia of Form B are occasionally seen with two necks. This is noted by Lagerberg, &c., to be the case also with occasional perithecia in *C. coerulea.* Difficulty was experienced in obtaining measurements of perithecia. *C. coerulea* consistently refused to produce perithecia either on malt agar, pine and cornmeal media, starch media, or on pine blocks. All measurements of this stage had, therefore, to be taken from Lagerberg, &c. They note that old strains of *C. coerulea* often do not fruit in culture. The same difficulty was experienced with *C. pilifera*—the first few sub-cultures produced perithecia, but after that none appeared. Form A produced perithecia, but these most often did not reach maturity, maturity being taken as the time when the ascospores are first discharged and remain suspended in an opalescent pale yellow droplet on the outstretched cilia.

It is in the characters of the cilia (Fig. 18) that most of the differences appear to arise in *C. coerulea, C. pilifera,* and Form B. The first has very long cilia—35-100μ—and there are about twenty-four per neck. Hedgcock gives no figures for his *C. pilifera* (Fr.) Winter, but in those observed by me in culture the range in length was from 9-24μ and the number per neck was about nine. This seems to separate the two species, and yet in Form B, which shows characters of both, the length varies from 15-50μ and the number per neck, while only nine (average) in culture, may reach thirty on wood, therefore bringing it into the province of both species.

Comparisons of the growth rates of the four forms at room temperature, 19°C., and 12°C., show that they all grow at approximately the same rate (see text-figure).

Comparative Description of the Four Forms.

1. *Cultural Appearance.*

(*a*) *C. pilifera.*—For a few days the colony is colourless, then the older parts become olive-green and a well-grown plate appears brown-black from beneath. On the upper surface arise colourless erect stranded hyphae which bear dendritically arranged conidia. This area of stranded hyphae may be confined to the centre but often extends further. If only present centrally the rest of the plate is cottony-white with abundant conidia. Sometimes conidial production is much less and the plate remains brownish

or blackish on top and faint radial ridges are visible on the upper surface. A definite acid smell is noticeable in older cultures. Hedgcock did not mention this latter fact.

(*b*) *C. coerulea.*—As given by Lagerberg, Lündberg, and Melin—"The mycelium forms a compact light-grey air mycelium which becomes a maze of filaments like wire-netting, and these fibres appear floury-white through the conidia. Underside of plate is green-black. Noticeable acid smell." In culture some variations of the above description were noticed. A well-grown colony appears deep green-brown with faint radial ridges. Centrally there arise numerous stout white strands of hyphae which give forth branches, and these bear conidia. These strands may attain a height of one cm. The rest of the plate may be covered similarly with these stranded hyphae or may be cottony-white with a felt of conidial-producing hyphae as in *C. pilifera.*

(*c*) Form A.—Commences growth as a colourless mat which in older cultures darkens to a brownish-black, shading to olive-green near the edge of the colony. Owing to a light dusting of conidia the upper surface often appears blue-grey. Air mycelium as in the two last types may be in the form of strands, although this is rare. Mostly it forms a cottony-white network on the surface and bears numerous conidia. Sometimes conidial formation is poor and the surface remains dry and faintly radially ridged. Older cultures often show thick, dirty-white patches of conidia centrally. There is a definite acid smell.

(*d*) Form B.—Shows similar characters to Form A, but conidial production has always been profuse. No occurrence of whitish moist conidial masses. A definite acid smell is noticeable.

2. *Hyphal Characters.*

In all cases hyphae at the outer edge of the colony are fine, hyaline, sparingly-branched and straight-sided. Further back the cells become claviform and brownish-green and are often rugose.

3. *Conidial Production.*

(*a*) *C. pilifera.*—Conidia are produced on the aerial hyphae and on submerged hyphae. The erect strands which arise from the surface of the plate consist of wefted hyphae. These bear fine branching hyphae from their sides, and these in their turn bear densely-packed conidia. On these superficial hyphae the conidia are mostly arranged in the so-called ear-shaped manner of Lagerberg, &c. The *Cephalosporium* type of arrangement is also seen where the conidia are arranged in grape-bunch clusters. This type is mostly submerged. Conidial production commences in two or three days.

(*b*) *C. coerulea.*—Conidial producing hyphae completely clothe the erect strands. Types of arrangement as for the last species.

(*c*) Form A.—Conidial arrangement as in the last two types. The *Cephalosporium* type of conidial arrangement is especially common.

(*d*) Form B.—Conidial arrangement as in the other three types. The *Cephalosporium* type of arrangement is not so common.

4. *Conidial Size and Shape.*

(*a*) *C. pilifera.*—Conidia are elongated, rounded at both ends, but usually more pointed towards the end of attachment. Larger conidia show irregularities in outline very often.

(*b*) *C. coerulea.*—Similar to last type in size and shape, but without such a great range in length.

(*c*) Form A.—Similar to other types. Great range in length (Fig. 15).

(*d*) Form B.—Similar to other types. Great range in length (Fig. 16).

Dimensions in Microns (μ).

——	*C. pilifera.*	*C. coerulea.*	Form A.	Form B.
Average length	6·6	5	8·0	9·7
Average diameter ..	2·3	2.1	2·7	2·6
Range in length	4–16	2.5–10	4·3–17	3·0–17
Range in diameter ..	1·5–3	2–2·5	1·7–4·3	1·7–4·3

For *C. coerulea* Lagerberg &c. give length of conidia as 5·6–11·2 μ.
diameter of conidia as 1·9–3·7 μ.

For *C. pilifera* Hedgcock gives length of conidia as 8–12 μ.
diameter of conidia as 2–4 μ.

5. *Perithecial Formation in Culture.*

(*a*) *C. pilifera.*—Perithecia commenced to appear in a few days, first as globular light-brown to black cellular bodies without necks, but with long hyphal appendages. They are fully ripe within a fortnight. In all malt-agar cultures except the very first lot, perithecia have been absent (Fig. 20).

(*b*) *C. coerulea.*—No perithecia were observed in culture or on wood. According to Lagerberg, &c., in malt agar perithecia appear in about ten days, and in general appearance and development they are apparently similar to those of *C. pilifera* described by Hedgcock.

(*c*) Form A.—Form A behaves very capriciously. Sometimes no perithecia are produced, and sometimes they have appeared within twelve days, but none have ever reached maturity. Immature perithecia are perfectly spherical, light-brown to black. Hyphal appendages spring from the whole surface, and are about 15-50μ in length. Most often they remain in this undeveloped state, but sometimes a neck is produced.

(*d*) Form B.—Each sub-culture has produced perithecia, at some times more abundantly than at others. They do not occur in concentric rings, but often in isolated patches commencing from the centre of the plate. They are fully developed in a fortnight. Both in culture and on wood there is a noticeable absence of conidial formation in the areas given over to the production of perithecia. Immature perithecia are the same as in the Form A and *C. pilifera.*

6. *Mature perithecia.*

In general characters the mature perithecium is the same in all four types. It consists of a somewhat globular black basal portion, which is slightly sunken into the surface of the medium, and it is attached by means of hyphal appendages. The neck is long and slender, and tapers at the apex to about half its basal diameter. It is black and smooth, and usually straight, but may be curved, and small irregularities are not uncommon. Just beneath the apex the neck pales to a brown colour, and the top spreads out to form a varying number of colourless cilia which support the spore drop (Fig. 17).

(*a*) *Neck.*

Dimensions.

——	*C. pilifera.*	*C. coerulea.*	Form A.	Form B.
Neck—				
Maximum length ..	1·4 mm.	1·5 mm.	400–500 μ	2 mm.
Cilia—				
Number average ..	about 9	24	about 9	about 9
Length average ..	19 μ	..	..	25 μ
Length range	9–24 μ	35·7–100 μ	5–17 μ	15–50 μ

Measurements for Form A were taken from what were probably immature perithecia.

(*b*) *Venter.*

(*a*) *C. pilifera.*—Practically spherical. Ratio of length to breadth variable. Perithecia measured here were immature, since no cilia or spore drops were visible. Hedgcock states, "perithecia are somewhat flattened basally."

(*b*) *C. coerulea.*—Lagerberg, &c., note that perithecia were nearly spherical, but flattened basally.

(*c*) Form A.—Ratio of length to breadth variable, but were mostly broader than long, and flattened slightly at the base.

(*d*) Form B.—Generally flattened at the base, but may be spherical or longer than broad.

Dimensions in Microns(μ).

—	*C. pilifera.*	*C. coerulea.*	Form A.	Form B.
Average length	142	..	161	166
,, diameter ..	147	..	167	187
Maximum length ..	..	240	200	250
,, diameter ..	..	288	220	280
Minimum length	..	144	..	..
,, diameter ..	..	160	..	..
Hedgcock's length ..	160	..	..	..
,, diameter ..	180	..	..	..

7. *Ascospores* (Fig. 21).

Ascospores, in every case, are of the same shape—they have been likened to orange quarters by some authors.

Dimensions in Microns(μ).

—	*C. pilifera.*	*C. coerulea.*	Form A.	Form B.
Average length	4·8	3·7–4·7	3·5	4·5
,, diameter ..	1·7	1·5–1·9	1·5	1·5
Hedgcock's length ..	5·5	..	..	..
,, diameter ..	2·5	..	..	..

In the case of Form B only were asci observed. As in the case of other species of *Ceratostomella,* they were slightly globular to pyriform in shape, and contained eight ascospores. Asci disintegrated fairly rapidly in water.

8. *Perithecial Occurrence on Wood.*

(*a*) *C. pilifera.*—Within three weeks after inoculation, perithecia appeared, but these remained stunted, and did not come to maturity.

(*b*) *C. coerulea.*—Lagerberg, &c., noted that, "on wood, perithecia take a month to become fully developed." None appeared on the inoculated blocks.

(*c*) Form A.—Perithecia commenced to appear within twelve days. Were not very abundant, and only the immature stages occurred—no necks were developed on the artificially infected experimental blocks. In natural infections, perithecia are large and well-developed.

Venter.—Average length, 220μ; average diameter, 200μ; maximum length, 230μ; maximum diameter, 210μ.

(*d*) Form B.—Perithecia appeared in profusion on the artificially infected blocks within seven days, and were ripe within three weeks. These perithecia are, on the whole, slightly larger

than those grown in culture, but the difference is practically negligible. In these perithecia, the number of cilia per neck may be much greater—sometimes rising to 30 per neck.

9. *Distribution of Hyphae in Wood.*

In all cases (i.e., in the four types studied) hyphae are most abundant in the rays, which are often as completely disorganized as those affected by *Hormonema.* Hyphae are also seen in the resin canals to a less extent, and also in the tracheids, where, on the whole, they are finer in size.

Hyphae in rays and resin canals are mostly brownish, and rather thick-walled, often becoming rugose.

Penetration from element to element takes place by direct penetration and not by way of the pits. This fact was also noted by Lagerberg, Lündberg, and Melin (Fig. 19).

V. Discussion.

The two Forms A and B isolated from Australian sap-stained timber would appear to be intermediate between the American and European species, and may form a link between them. Form A, in general appearance and number of cilia, is more like *C. pilifera,* but in size of perithecia it is closer to *C. coerulea.* Form B, in general appearance, is sometimes like *C. pilifera* and sometimes very like *C. coerulea.* Its perithecia in size are closer to those of *C. coerulea,* and are like those of this form, in that two necks occasionally occur. The average number of its cilia brings it close to *C. pilifera* and away from *C. coerulea,* and their range in length brings it sometimes into the province of *C. coerulea,* and again away from it. It seems that there is no constant difference between *C.* pilifera and *C. coerulea.*

If the European and American fungi do not belong to separate species (and our observations lead us to think they do not), then *C. pilifera* (Fr.) Winter should be relegated to synonymy, as Münch has shown that this old name really included a complex of forms, which he referred to as the *pilifera* group; so *C. coerulea* Münch should be used for the form under discussion in preference to *C. pilifera* (Fr.) Winter.

VI. Summary.

Two forms of *Ceratostomella* infecting *P. radiata* are described, which appear to form a link between the American *C. pilifera* (Fr.) Winter and the European *C. coerulea* Münch. It is suggested that the two latter forms are really variants of the same species, which should be known as *C. coerulea* Münch.

Hormonema dematioides Lagerberg and Melin is also described from blue-stained *P. radiata* case stock.

Figs. 1-21.

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Explanation of Figures 1-21.

Fig. 1. Young hypha with straight sided walls and lenticular septa. (× 1000.)

Fig. 2. Older hypha with rounded outer walls. W—lenticular wall of transverse septum. (× 1000.)

Fig. 3. (*a*) enormously thickened walls. (*b*) additional septations which have occurred. (× 1000.)

Fig. 4. Moniliform chains of cells. (× 600.)

Fig. 5. Bicellular portions of hyphae which are found in the oldest part of cultures.

Fig. 6. (*a*) portion of a hypha where resorption phenomenon has occurred. (*b*) a branchlet which is growing out from the still living cells of the hypha, through the old wall. (× 1000.)

Fig. 7. Diagram—× about 1000. c—*Coniothecium*-body situated on hyphae.

Fig. 8. Spores arising directly on hyphae.

Fig. 9. Spores, occasionally septated showing oil globules at poles.

Fig. 10. Diagram. s—sapwood. h—heartwood. sh—junction between sapwood and heartwood where the staining ceases abruptly. x—stained sector of sapwood.

Fig. 11. w—wall of medullary ray. p—pits in ray walls through which hyphae are passing. r—rugose thickened wall of hyphae.

Fig. 12. Ear-like fructification. Form B. Diagram. (× about 1000.)

Fig. 13. Form B—*Cephalosporium* type of fructification.

Fig. 14. (*a*) and (*b*) *Cephalosporium* type of fructification. (*c*) Conidiophore from which the conidia have fallen. Form A.

Fig. 15. Conidia of Form A (× 1000).

Fig. 16. Conidia of Form B (× 1000).

Fig. 17. Diagram of a typical perithecium which might have been produced by any one of the four forms. (× about 105.)

Fig. 18. Form B—neck apices with cilia. (× 1000.)

Fig. 19. t—tracheid wall. h—hypha penetrating wall. (× 1000.)

Fig. 20. Immature perithecia which might belong to any one of the four types. Diagram.

Fig. 21. Form B. (*a*) ascus containing ascospores. (*b*) ascospores. (× 1000.)